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WES M.P. 6-409 PROJECT HOBO, GROUTING SUPPORT AUG. 1960

PROJECT HOBO, GROUTING SUPPORT

MISCELLANEOUS PAPER NO. 6-409

August 1960

U. S. Army Engineer Waterways Experiment Station
CORPS OF ENGINEERS
Vicksburg, Mississippi

ARMY-MRC VICKSBURG, MISS.

PREFACE

All of the work performed by the U. S. Army Engineer Waterways Experiment Station in this project was accomplished in March and April 1960 for the Atomic Energy Commission under the direction and coordination of the University of California Lawrence Radiation Laboratory. This report covers only the grouting phase of the project; other phases will be reported by the responsible agencies as shown in Appendix B. It is desired to acknowledge the excellent cooperation, logistic support, and fine assistance that were furnished the WES by the organizations and personnel participating in these tests. Among these organizations were: U. S. Atomic Energy Commission; University of California Lawrence Radiation Laboratory; Holmes and Narver, Inc.; Reynolds Electrical and Engineering Co., Inc.; and Sandia Corporation.

This work was performed by Messrs. James M. Polatty, Project Officer, and Melvin Glass of the Concrete Division, Waterways Experiment Station. Col. Edmund H. Lang, CE, was Director, Mr. J. B. Tiffany was Technical Director, and Mr. T. B. Kennedy was Chief, Concrete Division, at the time of the tests and publication of this report.

CONTENTS

ABSTRACT

The grouting operation conducted in connection with Project HOBO consisted of four high-explosive shots made underground in tuff at the Nevada Test Site to permit a comparison between the seismic signal generated by a contained explosion in tuff and that produced by a tamped detonation in salt. To obtain shot data, three sets of instruments were placed in holes at the test site. Grouting mixtures were specially designed to match the density and sonic velocity of the in-situ material in which the instrument holes were drilled, and the instrument holes were pumped with these mixtures after the instruments were embedded. Three shot holes were drilled and pumped with a quick-setting grout mixture for containing the detonation of the high explosive, Pelletol, and a fourth hole was drilled and filled with a special set of mixtures to provide a dry hole for the detonation of the Pelletol. Field-cast grout specimens were tested in the laboratory. The field grouting was considered successful, and laboratory test results of the field-cast specimens checked the results of density tests made in the field.

PROJECT HOBO, GROUTING SUPPORT

INTRODUCTION

PURPOSE OF PROJECT

The purpose of this project, as given in the Technical Director's Operational Plan, was to permit a comparison between the seismic signal generated by a contained explosion in tuff and that produced by a tamped detonation in salt (Project COWBOY). Since a decoupling factor of 350 has been predicted between an explosion in a large hole in salt and a tamped explosion in tuff, the results of these experiments will determine to what extent the somewhat lower decoupling factors observed in Project COWBOY can be ascribed to the different behavior of tamped explosions in the two media. The existence of a medium decoupling factor like 2 or 3 would have a significance independent of the COWBOY results, for it would imply that media exist in which contained nuclear explosions would give considerably smaller (scaled) seismic signals than RANIER, BLANCA, and LOGAN, without the necessity for extensive underground excavation. The tests reported herein were conducted in connection with Project HOBO in corroboration of the foregoing theory and to extend the scope of Project COWBOY.

SCOPE OF GROUTING PHASE

The original plan for the grouting phase of Project HOBO included the drilling and grouting of three holes to contain the high explosives, commonly called shot holes, and three sets or 11 accessory instrument holes; however, a fourth shot hole was added after the completion of the original three. The test holes were located in the Main Drift of U12e.03 in area 12 of Nevada Test Site. The diameter and depth of the test holes are given in Table 1. This report describes the procedures used to satisfy the following: (1) the design and pumping of grout mixtures matching the in-situ densities and sonic velocities of the surrounding media, tuff, for the embedding of instruments; (2) the design and pumping of quick-setting grout mixtures for containing the detonation of the high explosive, Pelletol; and (3) the design and pumping of a special set of mixtures to provide a dry hole for the detonation of Pelletol.

MATERIALS, EQUIPMENT, AND PERSONNEL

MATERIALS

The following materials were used in the grout mixtures:

1. Portland cement, Type III (high early).
2. Frenchman Flat sand, a fine washed sand with 100 per cent passing the No. 16 sieve, secured from a stockpile at Frenchman Flat. (See Table 2.)
3. Magnetite sand, a fine sand with 98 per cent passing the No. 16 sieve. (See Table 2.)
4. Cal-Seal, gypsum cement, Halliburton No. 80.
5. On site water supply.

EQUIPMENT AND PERSONNEL

The U. S. Army Engineer Waterways Experiment Station (WES) furnished the following equipment and personnel:

1. Laboratory test kit containing equipment for making trial mixtures and molds for specimen casting.
2. Air-driven, paddle-type grout mixer of 5-cu-ft capacity.
3. Grout pump, air-driven.
4. One engineer and one engineering aide who served as pump operator and mechanic.

Lawrence Radiation Laboratory (LRL), Nevada Test Site, and Reynolds Electrical and Engineering Co. (REECo) furnished: four to five laborers, various hoses used in the grouting operations, engineering assistance, and all of the materials used in the work including the 3/4-in.-OD plastic pipe through which all of the grout mixtures were pumped into the holes. All holes were drilled by REECo under the supervision of LRL.

DESIGN CRITERIA AND MIXTURES FOR INSTRUMENT-HOLE GROUTING

SPECIFIC GRAVITY AND SONIC VELOCITY OF TUFF

The geology of the test area, furnished by the University of California Lawrence Radiation Laboratory, Nevada Test Site, indicated that there was considerable variation in the in-situ materials. This variation was verified by the range of specific gravity values of the cores obtained from the test holes.

The in-situ specific gravity and sonic velocity values used as criteria for the design of the grout mixtures for the instrument holes were all obtained from cores drilled from the test area. These values were furnished by the University of California Lawrence Radiation Laboratory, at both the Nevada Test Site and at Livermore. To obtain one value for each instrument hole, the specific gravity values obtained from the cores taken from depths at which the instruments would be placed were averaged. These values, both specific gravity and sonic velocity, are as follows:

Hole No.	Average of LRL Values for Desired Depth	
	Specific Gravity	Sonic Velocity, fps
1	2.13	9450
2	2.16	9900
3	2.14	8200
5	2.20	9400
12	1.83	8600
13	1.80	9200
14	1.82	8080
15	1.86	8250
16	1.84	9150
18	1.86	8675
22	1.76	7850

LABORATORY-DESIGNED MIXTURES

Because of time limitations, specific gravity and velocity values were available only for holes 12 through 22 prior to the start of work. Grout mixtures 1 through 4, designed at WES for these holes, had a density range of 1.65 to 2.0. Tests made later on the cores from holes 1 through 5 indicated a much higher density than for the others. It was therefore necessary that the grout mixtures for holes 1 through 5 be designed at the test site. These mixtures were numbered 5, 6, and 7. Design sonic velocity data for these mixtures were not determined because the necessary equipment was not available at the test site; however, a specimen was cast from the grout mixture used in hole 1 and shipped to WES for testing. Composition of all of these grout mixtures is given in Table 3.

MIXTURES USED IN FIELD

Using the test values determined from the laboratory mixtures, specific gravity curves were developed (fig. 1) so that the various in-situ specific gravities could be matched by the grout mixture used to embed the instruments. The actual proportions used in the mixtures for each hole are

[illegible]

[illegible]

BATCHING, MIXING, AND PUMPING

In proportioning the materials, mixing, [illegible] quantity of grout [illegible] to [illegible] of the [illegible] mixing operation consisted of placing the mixing water, the cement, the sand [illegible], and the Cal-Seal in the mixer. Calibrated [illegible] the correct amount of water was added. The mixtures were designed [illegible] standard sacks of cement and Cal-Seal; the sand, which had been previously screened and weighed, was in 50-lb sacks.

The grout mixtures were screened to remove all oversized particles or lumped materials prior to start of pumping.

GROUTING INSTRUMENT HOLES

In grouting the 11 instrument holes the first step was to lower the plastic hose to the bottom of the hole, then the agency in charge of the instruments, Stanford Research Institute, placed its instruments. All of the deep-set instruments were lowered into the hole with holding bars to properly orient them. After the instrument was in place, sufficient grout of the design density was pumped to securely embed the instrument, then the hose was withdrawn and cleaned.

After sufficient time had elapsed for the grout to harden, as determined from a test specimen made at the start of the pumping operations, the holding bars were released from the instrument and removed from the hole. Then the 3/4-IP hose was lowered to the new bottom of the hole and grout pumping started. The majority of the instrument holes were full of water due to either the high water table and or water left from the drilling operations, therefore the rise of the grout could be gaged by the flow of water from the hole. The grout hose was pulled from the hole at a sufficiently slow rate to insure that the discharge end was always in the grout. Withdrawal of the hose expedited the rate of pumping, which would have been slowed as a result of the grout head.

GROUTING SHOT HOLES

The shot chambers in the shot holes were reamed to the size shown in Table 1. It was required that the section of the hole which had been drilled to a depth below the shot chamber to allow the under-reamer to operate be filled with grout so that the bottom of the shot chamber would be flat. This was a very delicate operation since only meager information was available regarding the actual size of the area and the amount of spalling or drilling mud in the hole at the bottom of the shot chamber. For the first hole, hole 17, a quantity of grout calculated to fill this area was pumped; however, measurements after the grout had hardened indicated that a quantity of hardened grout was in the shot chamber. All of the other shot holes were grouted using a trial-and-error procedure: pumping, allowing to harden, and sounding. This method required as many as five pumping efforts, due to both possible irregularities in the drilled hole and ultra caution by WES engineers to insure that no grout entered the shot chamber.

When a hole was ready for the explosive, it was bailed as dry as possible and the explosive introduced. A pea gravel and/or sand layer was placed on top of the explosive, the grout hose was lowered to the bottom of the hole, and pumping commenced and continued until the hole was filled.

Since time was so limited between grouting and shooting, mixture 1, the quickest setting and highest strength grout (Table 3), was used to stem all of the shot holes.

GROUTING FOR WATER CONTROL

Since the Pelletol for the first three shots was placed in holes partially filled with water, hole 14A was an attempt to obtain data from a shot in a dry hole. This hole was completely drilled, including the shot chamber, and found to be filling with water. It was thought that the water was entering the hole through the shot chamber. In cooperation with REECo and LRL personnel, a procedure for grouting the hole to stop the entrance of the water was developed. The time schedule prevented conventional, pressure-type grouting, so as an alternate, it was decided to use a quick-setting grout and attempt by using the weight of the grout column as a surcharge to force the grout mixture out into the water-bearing fissures.

To expedite redrilling of the hole, the hole was divided into three sections for grouting: first, the shot chamber; second, the bottom 50 ft of the hole above the chamber; and third, the top 50 ft of the hole. Three grout mixtures with different times of set were designed for the three sections to provide grout with the fastest setting time for the third part, the top of the hole, and grout with the slowest setting time, yet fast enough to be set prior to drilling, for the first part, the shot chamber. By adjusting cement-Cal-Seal ratio and water content, the desired results were obtained and the redrilled hole appeared to be dry.

TESTS OF FIELD-CAST SPECIMENS

Various types of specimens were cast in the field during the pumping operations and sent to WES for check tests. These specimens consisted of two sets of three each 2- by 2- by 2-in. cubes, and three 6- by 12-in. cylinders. Density determinations were made on all nine specimens, the cubes were tested for compressive strength, and the cylinders for static and dynamic Young's modulus of elasticity, pulse and sonic velocity, and Poisson's ratio.

RESULTS

FIELD GROUTING RESULTS

The field grouting portion of this project was considered successful. Grout mixtures designed to match the in-situ density of the surrounding tuff were successfully pumped into the instrument holes. All of the instruments appeared to perform satisfactorily. No particular difficulty was experienced in any of the grouting work except for a little trouble that was evident after the successful pumping of hole 22. This hole was leaking water at the start of grouting, and required about twice the calculated volume of grout to fill. However, this condition was not observed in any of the other holes.

No explanation can be given by the grouting personnel for the fact that several of the holes would not take the calculated amount of explosives, nor for the nonfiring charge in hole 11. Particular care was taken in filling the drilled holes below the shot chambers after the trouble in hole 17. Appendix A describes a special investigation made at the job site to determine whether the grout would penetrate the layer of sand or gravel placed on top of the explosive in the shot holes.

It was noticed with several of the holes that large amounts of drilling mud necessary for drilling in the tuff had settled into the shot chamber and the small hole below the shot chamber.

RESULTS OF LABORATORY TESTS OF FIELD-CAST SPECIMENS

The results of laboratory tests of the field-cast specimens checked closely with the desired densities obtained from the cores. The test results are tabulated below:

Cubes

Hole No.	Mixture No.	Testing Age, Days	Specific Gravity	Compressive Strength, psi
11 (shot hole)	1	25	1.68	1160
3	12	21	2.14	480

6- by 12-in. Cylinders

Hole No.	Mixture No.	Testing Age, Days	Actual Specific Gravity	Modulus of Elasticity in Compression $E \times 10^{-6}$	Tensile Splitting Strength psi
22	8	34	1.74	0.73	148
13	10	27	1.70	0.63	144
1	13	20	2.09	0.35	64

6- by 12-in. Cylinders

Sonic Velocity ft/sec	Longitudinal Frequency cycles/sec	Flexural Frequency cycles/sec	Modulus of Elasticity	Poisson's Ratio
8695	3441	2115	1.099×10^{-6}	0.35
8080	3147	1979	0.921×10^{-6}	0.36
6785	2450	1520	0.681×10^{-6}	0.38

Table 1

Test Hole Data

Hole No.	Diameter in.	Design Depth, ft	Size of Shot Chamber, in., and Depth of Instruments, ft
1	6-3/4	100	98.6
2	6-3/4	101	100.2
3	6-3/4	102	100.2
4	11-3/4	108	Shot chamber, 30 in. diam, 31 in. high
5	6-3/4	106	96.3
11	12-1/2	108.5	Shot chamber, 30 in. diam, 29-1/2 in. high
12	6-3/4	102	100.2
13	6-3/4	102	100.2
14	6-3/4	103	100.2
15	6-3/4	101	98.4
16	6-3/4	102	100.2
17	12-1/2	108.3	Shot chamber, 18 in. diam, 24 in. high*
18	6-3/4	105	100.2
22	6-3/4	106	100.2
14A	11	108.5	Shot chamber, 30 in. diam, 42 in. high*

* No pre-shot survey made; values are design.

Table 2

Properties of Sands Used in Grout

Sieve No.	Cumulative Per Cent Passing: Frenchman Flat Fine Sand	Cumulative Per Cent Passing: Magnetite Sand
16	100	98
30	83	74
50	38	48
100	9	22
200	3	6
FM	1.70	1.59
Bulk specific gravity (SSD)	2.58	4.27
Absorption, per cent	2.2	0.9

Table 3

Laboratory-Designed Grout Mixtures

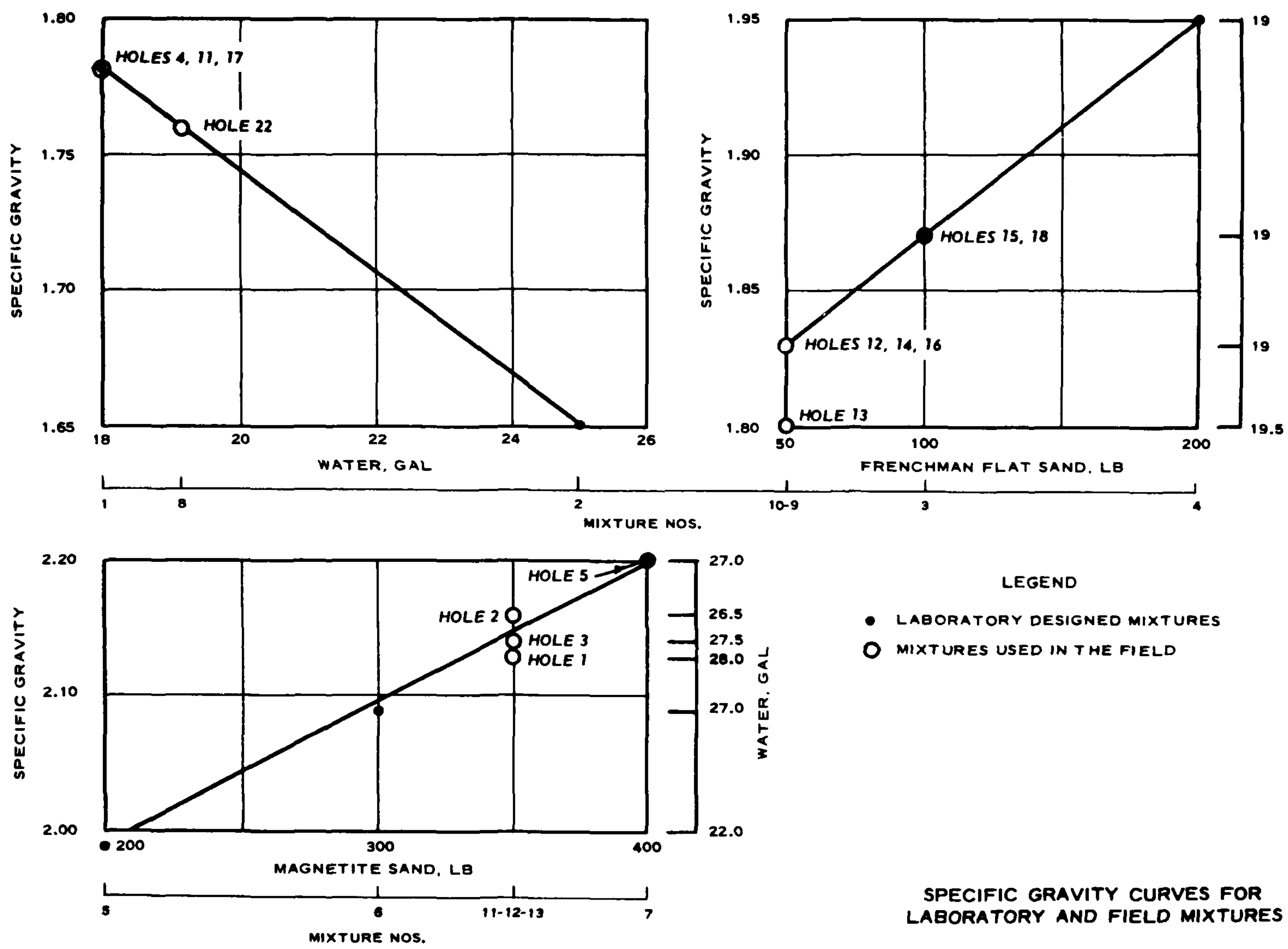
Mixture No.	High Early Portland Cement, lb	Cal-Seal lb	Water gal	Frenchman Flat Sand, lb	Magnetite Sand, lb
1	188	100	18	0	0
2	188	100	25	0	0
3	188	100	19	100	0
4	188	100	19	200	0
5	188	100	22	0	200
6	188	100	27	0	300
7	188	100	27	0	400

	Specific Gravity	Sonic Velocity, ft/sec			
		1 D	3 D	7 D	28 D
1	1.78	5,100	6,100	6,850	7,450
2	1.65	6,800	8,000	8,350	9,050
3	1.87	4,900	8,000	8,850	9,150
4	1.95	5,500	8,700	10,000	10,000
5	1.98	Designed at NTS - no data available			
6	2.09	Designed at NTS - no data available			
7	2.20	Designed at NTS - no data available			

Table 4

Mixtures Used in the Field

Hole No.	Mixture No.	High Early Cement lb	Cal-Seal lb	Water gal	Frenchman Flat Sand, lb	Magnetite Sand, lb	Estimated Specific Gravity of Grout
1	13	188	100	28.0	0	350	2.13
2	11	188	100	26.5	0	350	2.16
3	12	188	100	27.5	0	350	2.14
5	7	188	100	27.0	0	400	2.20
12, 14, 16	9	188	100	19.0	50	0	1.83
13	10	188	100	19.5	50	0	1.80
15, 18	3	188	100	19.0	100	0	1.87
22	8	188	100	19.0	0	0	1.76
4, 11, 17	1	188	100	18.0	0	0	1.78
14A(1)		188	200	35.0	0	0	--
(2)		376	100	38.0	0	0	--
(3)		376	0	32.5	0	0	--



SPECIFIC GRAVITY CURVES FOR LABORATORY AND FIELD MIXTURES

FIGURE 1

APPENDIX A

WESCC 20 April 1960

Dr. Vay Shelton
Lawrence Radiation Laboratory
P. O. Box 808
Livermore, California

Dear Vay:

At the request of Dr. Roger Preston, LRL, an investigation was made of the tendency of the grout mixture being used in Project HOBO to flow in a downward direction.

The procedure used in grouting the shot holes for Project HOBO and Project COWBOY has been to place about 250 lb of the fine sand, similar to that being used in the grout mixtures, on top of the Pelletol to act as a blanket to prevent the grout mixture from penetrating the Pelletol.

The materials used in this investigation included:

a. Cal-Seal - Halliburton No. 30.

b. Portland type III (high early) cement, California Portland Cement Company.

c. Tap water available at "E" Tunnel.

d. Sand A - a processed sand from the Frenchman Flat area having 100 per cent passing the No. 16 sieve and used in the sanded grout mixture used in this project. The grading of this sand, given in inclosure 1, is very similar to that used in Project COWBOY.

e. Sand B - a processed sand from the Frenchman Flat area, coarser than Sand A. The grading is given in inclosure 1.

WESCC
Dr. Vay Shelton

20 April 1960

f. Pea gravel - a processed coarse aggregate from the Frenchman Flat area with approximately 91 per cent passing the 3/8 in. sieve and 9 per cent passing the No. 4 sieve. The grading is given in inclosure 1.

The primary equipment used in this investigation consisted of three cans 6 in. in diameter and 12 in. high. The cans were made of wax impregnated paper with metal bottoms and are used for casting 6- by 12-in. concrete test specimens. In the metal bottom of each can a 4-in. diameter hole was cut; in the bottom of each can was placed first a piece of No. 16 screen wire 6 in. in diameter, followed by a piece of filter paper also 6 in. in diameter. A large piece of filter paper was placed on top of a dinner plate and the can assembly placed on top of the filter paper and dish. Then the aggregate was placed in the can to a thickness of approximately 3-7/8 in. and the fluid grout added.

For a secondary experiment a paper cut was used. The purpose in this part was to obtain information for comparative purposes on open and closed bottom containers. These cups were 3-1/4 in. in height, had tapered sides, and a volume of 182.5 cc. The aggregate was placed to a thickness of 3/4 in.; then the cup was filled with fluid grout.

Miscellaneous information concerning the primary experiment is as follows:

a. Temperature of the grout - 66 F.

b. Temperature of air - 59 F.

c. All of the aggregate and grout was introduced into the container through a restricted funnel in an attempt to produce a constant rate and flow of materials in order to obtain a uniform density.

d. The grout mixture used was: 94 lb cement, 59 lb Cal-Seal, 79 lb water.

e. With the plate, filter paper, screen, filter paper, and cylinder in testing position the aggregates were added. An attempt was made to level the surface prior to pouring in the fluid grout mixture. After 1 hr had elapsed and the grout had hardened, the filter paper below the cylinder and in the plate was reweighed. Two hours after the start of the test the cylinders were stripped and the moisture condition of the aggregates observed.

f. Sand A - fine grout sand:

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Dr. Vay Shelton

20 April 1960

(1) The weight of sand placed in the 6- by 12-in. cylinders was 2084 grams with an approximate thickness of 3-7/8 in.

(2) After 1 hr the bottom filter paper weighed 4.75 grams before test and 4.80 grams after test.

(3) The dinner plate felt dry 1 hr after the start of the test.

(4) The top 1 in. of the sand was damp while the bottom 2-7/8 in. was dry; all of the sand was in a free flowing condition.

g. Sand B - coarse sand:

(1) The weight of the sand placed in the 6- by 12-in. cylinder was 2548 grams with an approximate thickness of 3-7/8 in.

(2) After 1 hr the bottom filter paper weighed 4.75 grams before test and 4.80 grams after.

(3) One hour after the start of the test the dinner plate felt dry.

(4) The top portion, about 2-7/8 in., was damp while the bottom 1 in. was dry. The bottom 1 in. of the sand was in a free flowing condition.

h. Sand C - pea gravel:

(1) The weight of the gravel placed in the 6- by 12-in. cylinder was 2772 grams with an approximate thickness of 3-7/8 in.

(2) As soon as the grout was poured into the cylinder a small quantity appeared on one side of the bottom filter paper. In addition, the filter paper stuck to the screen and was wet. There was considerable moisture on the surface of the dinner plate.

(3) The inspection of the cylinder indicated that the weight of the grout had caused it to completely penetrate the gravel.

The results of the secondary experiment, using a paper cup, with the three sands, Sand A, Sand B, and Sand C, were similar to the results of the primary experiment, using a cylinder, with the three sands.

A4

:/ESCC
Dr. Vay Shelton

20 April 1960

A summary of the data on the materials and tests for the three aggregates is given below:

	Fine Sand	Coarse Sand	Pea Gravel
Loose specific gravity (bulk)	1.45	1.68	1.39
Loose unit weight (lb/cu ft)	90.4	104.2	84.6
Using a particle specific gravity of:	2.58*	2.54**	2.60*
Then:			
V_s	0.562	0.661	0.535
V_v	0.438	0.339	0.465
e (void ratio) %	78	52	87
Estimated permeability K in cm/sec	0.05	0.1	20

* Determined. ** Assumed.

The tests indicated that:

a. Grout by its own weight will completely penetrate pea gravel such as was used in this test.

b. In coarse sands with a high permeability the moisture from the grout will penetrate downward about 3 in.

c. A fine sand with a low permeability will allow moisture to penetrate in a downward direction only to approximately 1 in.

Sincerely,

JAMES M. POLATTY
Chief, Concrete Branch
Concrete Division

1 Incl
Tabulation

Copy furnished:
Dr. M. W. Knapp, LRL, Livermore
Dr. Roger Preston, LRL, Livermore
Mr. J. H. Nuckolls, LRL, Livermore
Mr. Don T. Schueler, LRL, Mercury
Mr. Walter P. Bennett, LRL, Mercury

Gradings of Aggregates from Frenchman Flat Stockpiles

Sand A - Fine Grout Sand

U. S. Sieve No.	Percentage Passing
16	100
30	83
50	38
100	9
200 (Wash)	4

Sand B - Coarse Concrete Sand

U. S. Sieve No.	Percentage Passing
4	100
8	91
16	27
30	14
50	7
100	5
200 (Wash)	4

Sand C - Pea Gravel

U. S. Sieve No.	Percentage Passing
1/2 in.	100
3/8 in.	91
No. 4	9

APPENDIX B

UNIVERSITY OF CALIFORNIA
LAWRENCE RADIATION LABORATORY

11 May 1960
UOPAC 60-143

MEMORANDUM

TO: J. E. Reeves, ALOO

SUBJ: Titles for Final Reports to be Issued by Agencies Participating in Project HOBO

Subject Titles are tabulated below.

Agency		Authors
LRL, Liv	Densities and Velocities Measured on Specimens from Instrument and Shot Holes, Project HOBO	R. S. Guido & S. E. Warner
WES	Grouting Support, Project HOBO	J. M. Polatty
UED	Shear and Compressional Velocity Measurements, Project HOBO	R. J. Swain, C. L. Heald & D. T. Snodgrass
SC	High-Explosives Arming & Firing, Project HOBO	R. J. Tockey, et al
APRL	Static Stress Determinations and Crushed Zone Measurements, Project HOBO	R. H. Merrill, et al
LRL-Nev	Geologic Background for Project HOBO	W. D. Richards & J. W. Skrove
SRI	Close-In Earth Motions, Project HOBO	L. M. Swift & W. M. Wells
LRL-Nev	Drilling and Survey Support, Project HOBO	W. P. Bennett et al

It appears now that LRL will write no analysis-type reports specifically concerned with Project HOBO data. Rather, results of analyses of data from this project will be incorporated into interpretations of Project COWBOY data.

/s/ D. D. Young, Jr.
for R. G. PRESTON

RGP:mhg

Info cc's to: S. E. Warner, LRL; J. M. Polatty, WES; L. A. Obert, APRL; J. L. Olsen, LRL-Nev; R. J. Tockey, SC; L. M. Swift, SRI

30055